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Growth of Native Grasses in the Mixed Prairie Near Hays, Kansas, in Relation to Past Intensity of Utilization

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GROWTH OF NATIVE GRASSES
IN THE MIXED PRAIRIE NEAR HAYS, KANSAS
IN RELATION TO PAST INTENSITY OF UTILIZATION

being

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THESIS ABSTRACT

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This investigation was an attempt to determine the seasonal development and seed production of the major grasses in areas which had been subjected to different intensities of grazing in past years. The grasses used in this study were (1) buffalo grass (Buchloe dactyloides); (2) blue grama (Bouteloua gracilis); (3) side-oats grama (B. curtipendula); (4) western wheatgrass (Agropyron smithii); (5) little bluestem (Andropogon scoparius); and (6) big bluestem (A. gerardi). Exclosures were established on upland and hillside sites of three pastures which were classified accordingly with past history of grazing as follows: (1) non-grazed; (2) moderately grazed; and (3) heavily grazed.

Precipitation was the primary limiting factor in this study. For two years preceding the investigation rainfall had been above normal. During the growing season of 1959, when this study was conducted, two mid-season droughts occurred.

After establishing exclosures in the grazed locations to prevent grazing, individual plants of each major species were designated to be measured and sketched weekly. Measurements recorded or calculated can be separated into five main categories as follows: (1) basal cover and composition; (2) weekly and cumulative height and length of leaves of each marked plant (verified by general notes); (3) seasonal forage yields; (4) number of tillers producing inflorescences; and (5) yield of caryopses.

Findings were as follows: (1) Basal cover of grasses increased with grazing, but less desirable species became more abundant. (2) Big bluestem was the latest major grass to initiate growth and did not begin until April

28; whereas, all others had started growth by April 1. (3) Blue grama flowered first and produced the greatest percentage of inflorescences in the heavily grazed location. (4) Western wheatgrass was greatly affected by drought and development of this species was poor in all areas. (5) Big and little bluestem were apparently affected most by grazing, and development of these species in the non-grazed prairie preceded the grazed locations. (6) Development of side-oats grama varied only slightly under the different intensities of grazing. (7) Forage production in the non-grazed location consistently yielded more than the moderately grazed pasture and produced nearly twice as much as the area heavily grazed. (8) The number of tillers producing inflorescences varied considerably with degree of grazing. Little bluestem and side-oats grama produced the greatest number of flower stalks in the non-grazed prairie; whereas, big bluestem, blue grama and western wheatgrass produced the greatest number in the heavily grazed area. (9) Yield of caryopses was poor for all species except hairy grama (Bouteloua hirsuta). Big and little bluestem produced no caryopses in the heavily grazed location. Side-oats grama, blue grama, and western wheatgrass produced the greatest number of caryopses under heavily grazed conditions.

Results of the various studies were also presented and illustrated by tables, figures and photographs.

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Dr. F. W. Albertson for suggesting the problem, for helpful aid and advice during the investigation, and for reading and criticizing the manuscript. Gratitude is also extended to Dr. G. W. Tomanek for helpful criticism in the preparation of this paper and to Bob Hyde for his aid in the pantographing and photography.

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INTRODUCTION

Much of the original grassland has been depleted by improper management. Consequently, native grasses of the mixed prairie have been the subject of many extensive investigations. As more knowledge is gained, the importance of conserving grasslands is further emphasized. Adequate stocking rates during the proper season are recognized by range technicians as one of the most important factors in assuring sustained yields from the native prairie. At present, the practice of range reseeding is being applied on a large scale, and an adequate supply of grass seed is needed.

The first complex investigation of the mixed prairie, especially near Hays, was that of Albertson (1937) and later studies by him have supplied vast quantities of information on the complexities of the prairie (Albertson, 1938; 1939; 1941; 1942; and others). Publications by Albertson and Weaver (1942), and Weaver and Albertson (1944; 1956) are of great value to ecological studies of the prairie. Some pertinent publications involving effects of grazing are those by Sarvis (1923), Hanson and Stoddart (1940), Tomanek (1948), and Tomanek and Albertson (1953). Studies of individual species and life histories (Anderson and Aldous, 1938; Riegel, 1940 and 1941; Branson, 1941; Hopkins, 1941; Webb, 1941; Cornelius and Melcher, 1942; Brown, 1943; Rice, 1950; and Kneebone, 1955) have supplied much valuable information to the literature, and were of great assistance in the present investigation.

A review of literature revealed that very few investigations have been concerned with seasonal development of native grasses. To the author's knowledge no such study has been published on the development of

major grasses during any definite growing season or under different intensities of past utilization. The need for information pertaining to the development of native grasses was instrumental in suggesting this investigation. Thus, the primary objectives of this study were to determine the seasonal development and seed production of the major grasses in the mixed prairie, under various intensities of utilization during past years.

Scientific names of grasses used in this study are those of Hitchcock and Chase (1950), while nomenclature for other herbaceous vegetation follows Rydberg (1932).

METHODS OF STUDY

Three pastures were selected for study. They were chosen and classified with reference to the intensity of grazing to which they had been subjected during past years. Observations upon general appearance of the vegetation were also used for determining the exact study locations. Within each of the three pastures differentiation for study purposes was made between the hillside and upland sites, corresponding to that made by Albertson (1937).

A detailed study of the differences of these three pastures was made along the following lines: Basal cover and composition, seasonal yields, growth of the grasses in height, floral development and period of anthesis, the period of seed development, and the amount of seed produced. Data concerning climatic conditions were obtained from the Hays records of the United States Department of Commerce Climatological Data.

Representative areas of upland and hillside sites of the three pastures were selected for study. With exception of the non-grazed location,

the areas selected for study were protected from grazing by exclosures for the entire growing season of 1959. Three to five exclosures, each enclosing a meter square quadrat, were established at each site. In order to study the development of major grasses, the exclosures were placed in such a manner as to include areas representative of the intensity of utilization, and to include all of the major grasses under consideration.

Individual plants of the major species in each area were selected, measured and sketched weekly to determine the seasonal development. The grasses selected for this study were buffalo grass (Buchloe dactyloides), blue grama (Bouteloua gracilis), side-oats grama (B. curtipendula), western wheatgrass (Agropyron smithii), little bluestem (Andropogon scoparius), and big bluestem (A. gerardi). Field notes were taken each week to supplement and verify the measurements of the individual plants. Since individual plants of the dioecious buffalo grass were extremely difficult to measure, only general observations were made upon the floral development of this species.

When each species had completed inflorescence development, counts were made to determine the percentage of tillers producing flower stalks. These counts were made at random within the exclosures until two to three hundred tillers were recorded. From this, the number of flower stalks per 100 tillers was determined.

Samples of grass seed of each species from each area were collected at the end of the growing season. Each sample was placed in a paper bag and the date, location and habitat recorded at the time of collection. The sample was then brought into the laboratory and threshed. Determina-

tion of the percentage of caryopses present in each sample was made by placing the entire sample on a table. One hundred florets were then randomly selected by taking a few florets from each portion of the sample. The hundred florets selected were spread on a glass table illuminated from below by electric light. Empty florets appeared transparent, while those containing caryopses, smut, or unopened anthers were opaque. All florets that appeared to contain caryopses were dissected in order to eliminate those containing smut or unopened anthers. At least 200 florets of each species from each location were counted to determine per cent yield of caryopses. More were counted if the first two one-hundred samples disclosed no caryopses, or if there occurred a vast difference in number of caryopses.

Florets of blue grama and hairy grama were placed in a bleach solution similar to that described by Wright and Streetman (1959). Inflorescences of these species were placed in an 0.8 per cent solution of clorox (active ingredient is sodium hypochlorite) for approximately 48 hours. This process bleaches the glumes, lemma, and palea sufficiently to make the caryopses visible.

Basal cover and composition were estimated and charted in all the quadrats with a pantograph at the end of the growing season. In charting, only areas without cover of native grasses larger than one inch in diameter were considered bare. The percentage basal composition of each species in all quadrats was computed by use of a planimeter. Basal cover of western wheatgrass was determined by use of the regression line as described by Martin et al. (1955). Average of all the quadrats in each location was used as the representative vegetative cover for the area.

At the end of the growing season all of the quadrats were clipped to determine seasonal yields. Each species of each quadrat was clipped, placed individually in a paper bag, appropriately labeled and allowed to air dry. Average weight of air dried forage was computed from each study site and converted to pounds per acre to represent the forage yield for that location.

STUDY AREAS

The pastures selected for study are located near Hays, Kansas. All three pastures are approximately 2.5 miles west of Hays, and all are located within two miles of each other. Rolling topography is characteristic of this general area. The altitude varies from approximately 2000 feet in the lowlands to about 2200 feet on the highest hills.

The vegetation of this general area has undergone many striking changes in response to cyclic climatic conditions. During periods of drought the vegetation is greatly reduced and many undesirable plants gain in abundance (Weaver and Albertson, 1944). It has been found, however, that during normal or above-normal years that follow drought, the pastures recover quite rapidly. The vegetation was recovering from a drought at the time of this study. The years of 1952-1956 were droughty, whereas, during 1957-1958, rainfall was above average and therefore, the pastures had recovered to near the pre-drought conditions by 1959 when the study was initiated.

History of the pastures with respect to past grazing was obtained from the owner and from records kept by the college.

The first area of study comprised approximately 35 acres. It is a part of the Fort Hays Kansas State College farm, and is generally referred

to as the "relict area." Grazing has been excluded from this grassland since about 1902. Consequently, the vegetation is approaching climax condition.

Upland in the non-grazed location was dominated largely by big bluestem and side-oats grama (Fig. 1). Blue grama formed an understory in the open areas. Little bluestem and western wheatgrass were found in lesser amounts dispersed throughout the upland. Many forbs were also found on the upland. Lead plant (Amorpha canescens) and wild alfalfa (Psoralidum tenuiflorum) were two of the most common forbs found in this location.

Big bluestem, side-oats grama and little bluestem were the most important dominants on this hillside (Fig. 2). Blue grama was also found growing on the deeper soils of this location. Numerous forbs occurred throughout the area.

In the non-grazed grassland a dense layer of mulch four to eight inches deep was often found. The general appearance was one of high foliage cover and low basal cover. The grasses grew in rather dense bunches often separated by large bare spaces covered by deep mulch.

The second area of study comprised approximately 800 acres of moderately grazed prairie located about 2.5 miles west of Hays. This prairie is a portion of that operated by the college farm. The area was fenced and has been moderately grazed by cattle during a major portion of the time since its acquisition in 1900.

The moderately grazed uplands are characterized by a short grass type of vegetation (Albertson, 1937). Blue grama and buffalo grass were two of the most common species of upland vegetation (Fig. 3). Side-oats

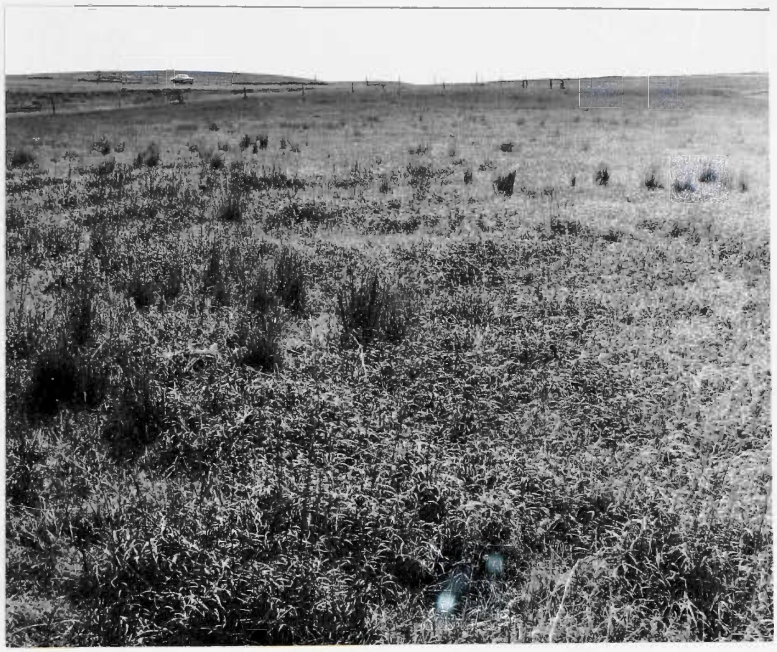

Fig. 1. Non-grazed upland. Scattered bunches of little bluestem surrounded by a dense growth of big bluestem, side-oats grama, and blue grama characterized this area.

Fig. 2. General view of non-grazed hillside showing characteristic bunches of little bluestem and the uniform cover of big bluestem and side-oats grama.

Fig. 3. Moderately grazed upland prairie showing the dense cover of short grasses and scattered clumps of side-oats grama.

grama, a mid grass, was also of great importance on this site. Western wheatgrass was common throughout, but was of greater abundance in slight depressions. Other grasses including three-awn (Aristida spp.) and sand dropseed (Sporobolus cryptandrus) were found in lesser amounts scattered over the uplands.

The hillside site is characterized by the occurrence of little bluestem, big bluestem, side-oats grama and to a lesser extent by blue grama and hairy grama (Bouteloua hirsuta) (Fig. 4). Numerous forbs were also common throughout the growing season. Outcroppings of the Fort Hays Limestone were relatively common on the steeper slopes.

The third area of study consisted of about 120 acres of heavily grazed prairie located adjacent to the non-grazed location. This pasture had been extensively overstocked until 1957. Since 1957, however, the owner of the pasture has been practicing rotational grazing; consequently, the vegetative conditions have improved. Even though a vast difference in composition was still evident between the heavily grazed and moderately grazed pastures, remnants of the more desirable grasses were increasing in abundance in the former.

Vegetative composition of the heavily grazed upland pasture was comprised almost entirely of blue grama and buffalo grass (Fig. 5). Scattered bunches of side-oats grama and western wheatgrass occurred in favored locations. Bunches of sand dropseed and three-awn grasses were also found scattered throughout the area.

Basal cover of the upland was relatively high as the short grasses formed a dense sod. Little mulch accumulation could be noted. The grasses were apparently reduced in stature as a result of heavy utilization

Fig. 4. Moderately grazed hillside prairie supporting a mixture of short and mid grasses.

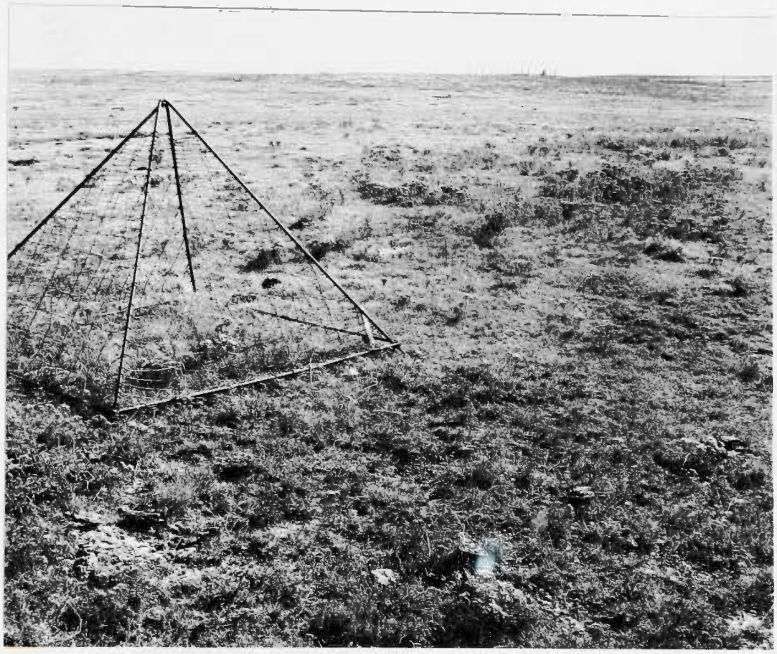

Fig. 5. Vegetation of the heavily grazed upland pasture was composed almost entirely of the short grasses, blue grama and buffalo grass. Forbs scattered throughout the area are broom snakeweed (Gutierrezia sarothrae).

during past years. The drought resistant and unpalatable broom snakeweed (Gutierrezia sarothrae) was the most abundant forb in this location.

The hillside site of the heavily grazed pasture supported a mixture of short and mid-grasses (Fig. 6). Buffalo grass, big bluestem and sideoats grama shared nearly equal abundance in the vegetative composition. Little bluestem had been greatly reduced and in this area were found such short-lived grasses as tumblegrass (Schedonnardus paniculatus) and hairy dropseed (Sporobolus pilosus). Forbs common on the hillside site were numerous.

Bare areas and erosion were evident on the slopes of the heavily grazed location. Cattle trails leading from the upland to the pond of water in the lowland had eroded until little or no soil was left. Limestone outcroppings were common and, due to the denuded condition, they were quite obvious.

CLIMATIC CONDITIONS

General climatic conditions during the growing season of 1959 were somewhat unfavorable for plant growth. The last freeze was on April 22, and by May 2, the temperature had increased to 96 degrees F. It was hot throughout May and June with both months experiencing above normal temperature (Table I).

When compared with long term averages, July was cool. Average maximum temperature during July was 86.7 degrees and the highest temperature recorded was 98 degrees. During August the temperature ranged 2.8 degrees above normal. The average maximum temperature was 95.2 degrees and for 13 days, of which six were consecutive, the maximum temperature was 99 degrees or above. Temperatures remained relatively high during the first

Fig. 6. General view of heavily grazed hillside showing characteristic limestone outcroppings and evidence of erosion in the background. The light colored in the foreground is buffalo grass, the darker areas are big bluestem and side-oats grama.

TABLE I. The temperature, rainfall, and evaporation for the growing season of 1959, at Hays, Kansas.

Month	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	
			Temperature (Degrees F.)				
Average Max.	64.5	76.2	87.5	86.7	95.2	80.8	
			Rainfall (Inches)				TOTAL
1959	.53	6.40	1.55	3.62	2.25	4.69	19.04
Normal	1.93	3.78	4.37	2.55	2.92	2.21	17.76
Deviation	-1.60	2.62	-2.72	1.07	-.67	2.48	1.28
			Evaporation (Inches)				
1959	8.41	9.40	13.34	11.93	16.23	10.73	70.10
Normal	7.99	9.63	15.08	15.08	13.47	11.13	72.38
Deviation	.42	-.23	-1.74	-3.15	2.76	- .40	-2.28

10 days of September, but then decreased. The average maximum temperature was 80.8 degrees, and temperatures exceeded 100 degrees for only three days during the first part of the month.

Total rainfall for the growing season of 1959 (April to September, inclusive) was 19.04 inches which was 1.28 inches above normal (Table I). For the months of April, June, and August, however, it was below normal. Rainfall during April and June was less than half normal, whereas during May, July, and September it was considerably above normal.

From the data given above it is evident that precipitation was cyclic and that two mid-season drought periods occurred. During April rain occurred only five times and .31 inch of the total of .53 inch, fell on April 18. Even though May was a month of above average precipitation, no rainfall was recorded during the period from May 10 to May 20. During the dry month of June, no rainfall occurred from June 6 to June 21. Temperatures during this period were above normal. However, lower temperatures were characteristic during July and rainfall exceeded the normal by 1.07 inches. August was a month of below normal precipitation, and average temperatures ranged 2.8 degrees above normal. Rainfall during September was 2.48 inches above normal. From September 2 until September 17, however, no rain fell, and temperatures ranged above normal.

Evaporation from a free water surface was 2.28 inches below normal during the 1959 growing season. However, during the months of April and August evaporation was above normal. May and September were near normal, and June and July were considerably below.

RESULTS

Basal Cover and Composition

Basal cover on the non-grazed upland averaged 36.27 per cent (Table II). Side-oats grama was the most abundant grass in this area, comprising 42.35 per cent of the vegetative composition. Big bluestem and blue grama shared almost equal abundance, the former contributing 25.28 per cent of the composition and the latter 20.51 per cent. On the shallower soils small scattered clumps of little bluestem were found. They averaged 6.56 per cent of the composition on the general upland area. Western wheatgrass comprised 1.65 per cent of the composition and the remaining 3.46 per cent of the vegetation was made up of other grasses such as tall dropseed (Sporobolus asper), three-awn grasses and hairy dropseed. The cover was composed mainly of large clumps of side-oats grama, big bluestem and blue grama (Fig. 7). Spaces bare of perennial grasses were covered by a layer of mulch and very few open areas occurred. The foliage cover in this non-grazed location was nearly 100 per cent (Fig. 8).

Total basal cover of the moderately grazed upland was 41.3 per cent. Blue grama was the principal grass comprising 40.61 per cent of the vegetative composition as compared to 29.27 per cent for side-oats grama and 20.8 per cent for buffalo grass (Table II). Western wheatgrass was relatively common here and made up 5.3 per cent of the composition. Big bluestem was found in widely dispersed clumps and averaged only 1.84 per cent of the composition. The remaining 3.46 per cent was contributed by three-awn grasses and sand dropseed. Blue grama and buffalo grass formed a relatively dense sod over the moderately grazed upland (Fig. 9). Side-oats grama occurred commonly in large clumps dispersed among the short grasses.

TABLE II: Species composition and basal cover of grasses on the upland locations from each degree of past utilization.

	Per cent composition		
SPECIES	Non-Grazed	Mod. Grazed	Heavily Grazed
Little Bluestem	6.56		
Big Bluestem	25.28	1.84	
Side-oats Grama	42.35	29.27	4.65
Blue Grama	20.51	40.61	54.89
Western Wheatgrass	1.65	5.30	.92
Buffalo Grass		20.80	39.40
Other Grasses	3.46	2.18	.14
Basal Cover	36.27	41.30	55.31

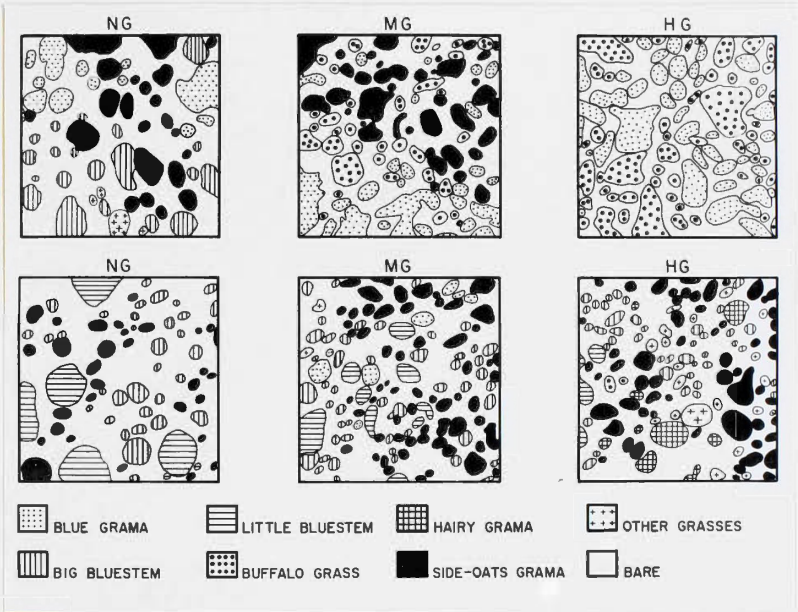

Fig. 7. Quadrats (one square meter) showing basal cover and characteristic structure of grasses on upland (upper) and hillside (lower) sites under each condition of past utilization.

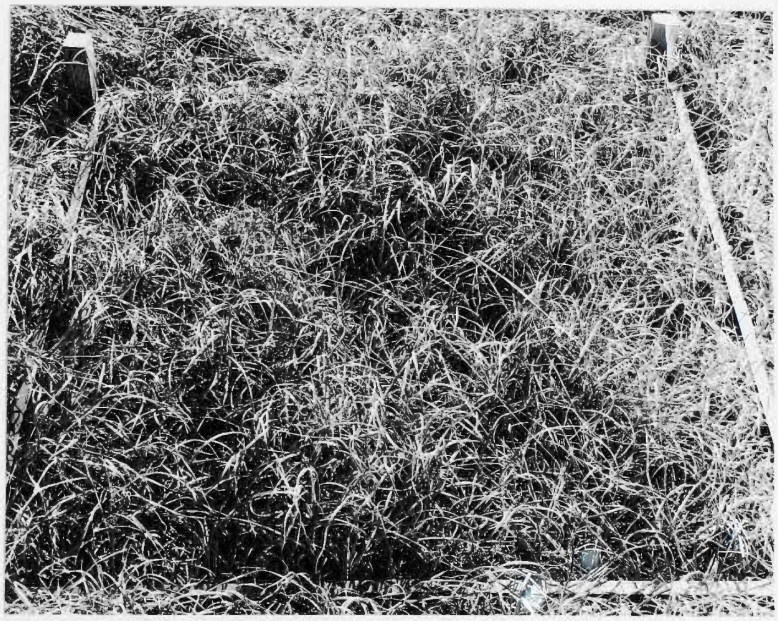

Fig. 8. Meter quadrat on non-grazed upland showing dense foliage cover of side-oats grama, big bluestem and blue grama.

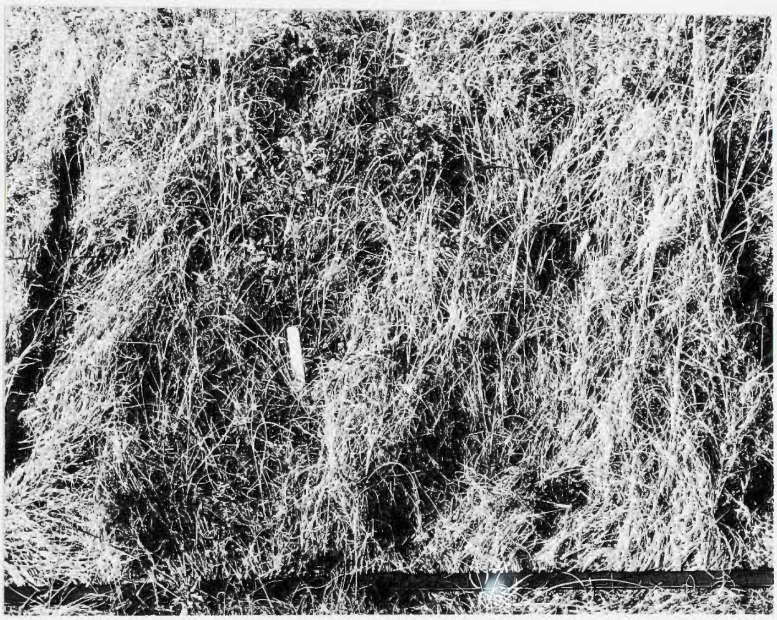

Fig. 9. Typical quadrat in moderately grazed upland prairie. Blue grama is the principal grass. Buffalo grass, side-oats grama and western wheatgrass were also common at this location.

The heavily grazed upland was composed almost entirely of blue grama and buffalo grass, being, respectively, 54.89 and 39.4 per cent of the vegetative composition (Table II). Average basal cover of the heavily grazed upland was 55.31 per cent. Side-oats grama was found only in small clumps and amounted to 4.65 per cent of the composition, while western wheatgrass was widely dispersed and averaged only .92 per cent. The short grasses were somewhat reduced in stature and formed a dense mat over the upland (Fig. 10). Numerous buffalo grass stolons were apparent over most of the area.

Average basal cover on the non-grazed hillside was 28.48 per cent (Table III). Big bluestem and side-oats grama were the most abundant species composing 32.35 and 32.11 per cent, respectively, of the composition. Large clumps of little bluestem were common and this species formed 23.44 per cent of the composition. Blue grama, found in localized clumps, comprised 10.8 per cent of the vegetative composition. The characteristic vegetative form of the non-grazed hillside was that of large clumps of little bluestem with a rather uniform stand of smaller bunches of big bluestem and side-oats grama dispersed throughout (Fig. 11).

Side-oats grama was the most abundant grass on the moderately grazed hillside, comprising 48.32 per cent of the 32.39 per cent basal cover (Table III). Big and little bluestem contributed 22.04 and 17.47 per cent of the composition, respectively. Clumps of blue grama were common and formed 7.78 per cent of the composition. Bare spaces between the bunches of perennial grasses were common and only a small amount of mulch was present (Fig. 12).

Basal cover of the heavily grazed hillside was 42.87 per cent, of which 35.74 per cent was buffalo grass (Table III). Big bluestem and

Fig. 10. Quadrat showing the characteristic dense sod formed by blue grama and buffalo grass on heavily grazed upland.

TABLE III. Species composition and basal cover of grasses on the hillside sites from each degree of past utilization.

	Per cent composition		
SPECIES	Non-Grazed	Mod. Grazed	Heavily Grazed
Little Bluestem	23.44	17.47	1.89
Big Bluestem	32.35	22.04	30.25
Side-oats Grama	32.11	48.32	26.31
Blue Grama	10.80	7.78	
Buffalo Grass			35.74
Other Grasses	1.30	4.39	5.81
Basal Cover	28.48	32.39	42.87

Fig. 11. A typical quadrat on the non-grazed hillside. Big bluestem and side-oats grama occupy the area between large clumps of little bluestem.

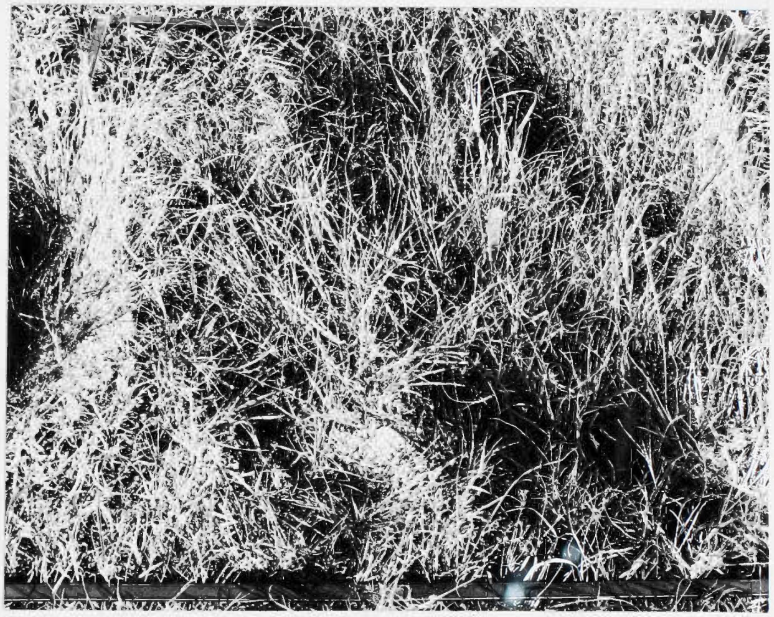

Fig. 12. Quadrat view of moderately grazed hillside. Sideoats grama, big bluestem, and little bluestem are the most important grasses. Little mulch was found and bare spaces such as the one in the foreground were common.

side-oats grama occurred in scattered clumps and composed 30.25 and 26.31 per cent of the composition, respectively. Little bluestem was widely dispersed and yielded only 1.89 per cent of the vegetative composition. Other grasses including three-awn, sand dropseed, hairy grama and tumble-grass made up 5.81 per cent of the basal cover. Bare spaces were relatively common and little or no mulch was found (Fig. 13).

Seasonal Development of the Major Grasses

For the most part, all of the major grasses had initiated growth by April 15. By this time most of the plants had produced two to four leaves. Growth progressed at a relatively uniform rate until mid-June. At this time conditions of drought prevailed and little or no growth was noted. During July, however, when moisture conditions were favorable, growth rate was somewhat accelerated. During the month of August, drought was again prevalent, and from July 28 to August 9, growth of all grasses was almost nil. Growth remained relatively slow until mid-September. After September 18, however, rainfall was above average and growth was again quite rapid. Development of major grasses on each site will be discussed individually as to species.

Blue Grama

By April 1, blue grama had initiated growth in all three upland locations (Fig. 14). Development of this species in the non-grazed location was at first somewhat inconspicuous as a result of the existing mulch. By June 1, the leaves of blue grama had reached a height of four inches in the heavily grazed area, and 9.5 inches in the moderately grazed and non-grazed locations. Very little increase in increment was recorded for the

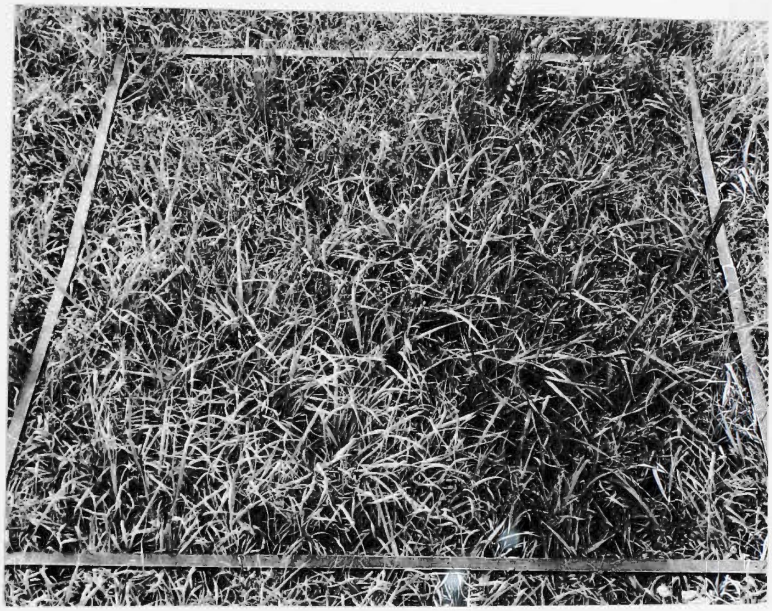

Fig. 13. View of representative quadrat on heavily grazed hillside. Small clumps of little bluestem are visible in the background. Other grasses include side-oats grama, big bluestem, buffalo grass, and three-awn. Dark areas are bare spaces.

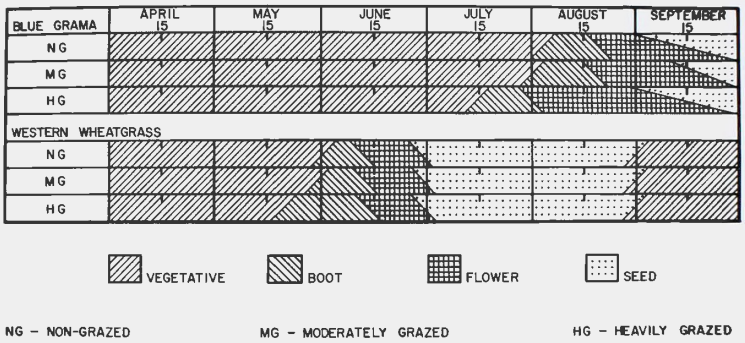

Fig. 14. Seasonal development by dates and growth stages of major grasses under different intensities of past utilization.

remainder of the growing season in the three areas (Fig. 15). Average total growth for blue grama was 10.5, 10.25, and 5.0 inches for the non-grazed, moderately grazed and heavily grazed locations, respectively. Of the total increment, slightly over 80 per cent occurred during the first half of the growing season. Average height of flower stalks was 17 inches in the non-grazed, 13 inches in the moderately grazed, and eight inches in the heavily grazed area (Fig. 16).

Blue grama suffered from effects of drought during the month of June, and very little growth occurred from June 14 until June 28. With exception in the favored areas, blue grama leaves were rolled from the margin inward. The tips of many of the leaves dried to a brownish color and did not recover. Many of the basal leaves dried and fell off. During July growth again became evident. Very little increase in height was noted, but in all cases, an average of one new leaf per plant was produced. The period from July 25 to August 14 was again dry, and blue grama assumed a somewhat dormant condition. Rainfall amounts of .28, .18, and .26 inch occurred during August 14, 15, and 16, respectively. Growth was rapid after the rains and within four days blue grama was profusely producing inflorescences in the grazed pastures.

Floral development was somewhat retarded during the August drought. Many of the plants in all three locations were forming inflorescences within the enclosed sheath when drought occurred. These plants dried and floral development was halted. Blue grama plants in the heavily grazed upland were developing inflorescences as early as July 10. However, very few of the earlier inflorescences developed beyond the boot stage and the first inflorescences to protrude were noted August 1. Heads produced dur-

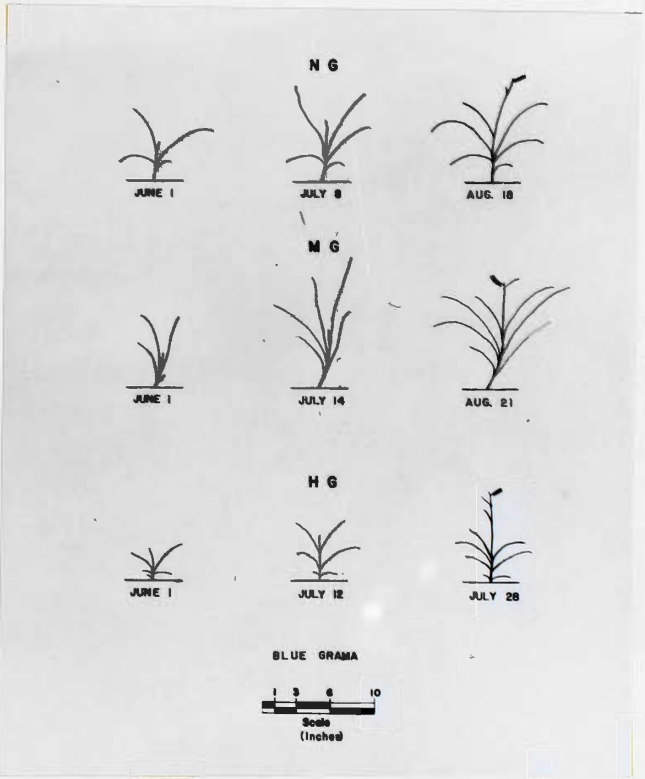

Fig. 15. Blue grama. Sketches represent development of typical individuals under three degrees of past utilization.

Fig. 16. Representative samples of blue grama plants from each location at time of flowering. Scale behind the sample from the moderately grazed location is in feet.

ing this time were dried, and for the most part, the anthers did not open. Following the rains of August 14, 15, and 16, development was very rapid and within a week many inflorescences were noted. The most active period of anthesis occurred during the two weeks of August 18 to September 1. Flowering continued throughout August and September, and was prolonged somewhat by the early fall rains. The first seed ripened about September 1. Many of the earlier heads did not develop fully; thus, seed production at this time was light.

Development of blue grama on the moderately grazed upland followed much the same course as it did under heavily grazed conditions. The plants first formed inflorescences within the boot during late July. However, no inflorescences were produced until after the mid-August rains. Flowering extended throughout August and September and many new heads were produced after the early fall rains. The first seed was set by September 8, and immature caryopses continued to mature until the first frost on October 17.

In the non-grazed location development was somewhat slower than in the grazed areas. Growth was initiated at approximately the same time but due to the existing mulch, development occurred at a slower rate. No inflorescence development was found within the boot until August 1. By August 7, elongation of the flower stalks was evident, and after the rain, inflorescence development was obvious. For the most part, flower stalks in the non-grazed area were somewhat elongated as compared to those in the grazed areas, and they ranged from one to two inches greater in length.

Western Wheatgrass

Western wheatgrass, a cool season perennial, had produced quite a large amount of growth by April 1. Total average increment at the end of

the growing season in the non-grazed, moderately grazed and heavily grazed uplands was 15, 15 and 7.5 inches, respectively. Nearly 100 per cent of the total growth was produced during the first half of the growing season. The average number of leaves produced per individual plant in the non-grazed location was 5.3, while in the moderately grazed it was seven, and in the heavily grazed 5.3 per plant. However, a vast difference in stature existed between the plants in the heavily grazed area and those in the moderately grazed and non-grazed locations (Figs. 17, 18).

During the June drought western wheatgrass was greatly affected in all three locations. Inflorescence development was initiated by May 17 on the heavily grazed area, by May 22 on the moderately grazed pasture, and by May 27 on the non-grazed location (Fig. 14). Initial development seemed to progress normally, but when moisture conditions became unfavorable growth was retarded. Many of the plants dried, and inflorescence development did not progress beyond the boot stage. A large portion of the few heads that did extend beyond the boot dried before pollination could occur. Rainfall amounts of .12, .33, and .03 inch occurred on the days of June 21, 22, and 23, respectively. After this time several new heads were produced, but in general, inflorescence development was poor. By July 4, the western wheatgrass plants were again drying and growth from this time until late August was almost nil.

During the latter days of August western wheatgrass again initiated new growth. Fall growth was abundant during September and October, and quite a large amount of forage was produced during this time.

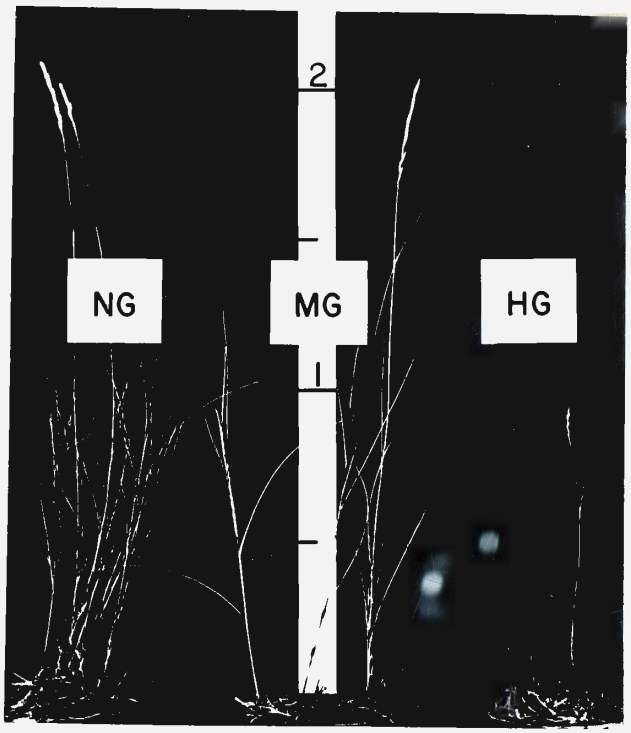

Fig. 17. Western wheatgrass from each area at time of seed production. Scale in feet.

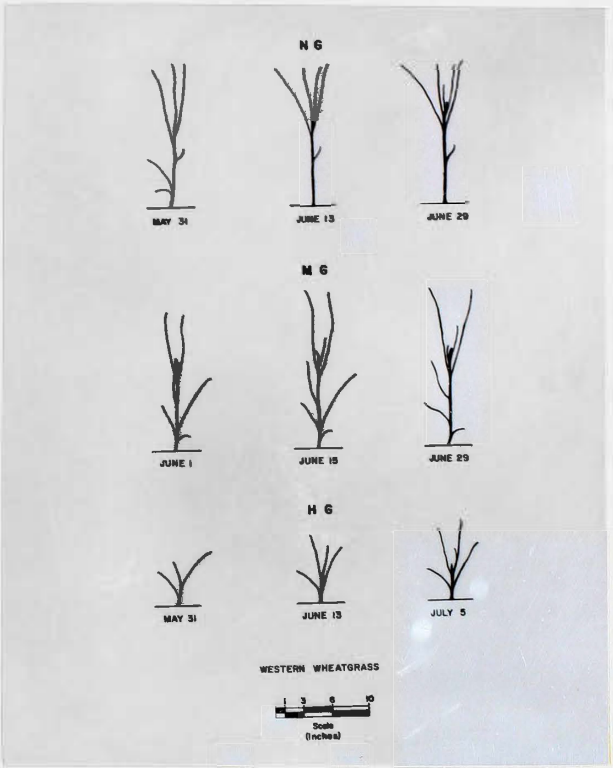

Fig. 18. Sketches of individual plants of western wheatgrass from upland locations, representing the different stages of development. Extremely few heads were produced, and none of the selected plants flowered.

Buffalo Grass

Buffalo grass was found only in the grazed locations and only general observations were conducted on the floral development of this species. Growth of buffalo grass was evident in the grazed locations by March 20, and by June 1, it had grown to an average height of 5.75 inches in the moderately grazed and 3.67 inches in the heavily grazed locations. Total increment for the complete growing season was 6.5 and 4.5 inches, respectively, under the two degrees of grazing. During the two periods of drought buffalo grass more or less assumed a semi-dormant condition and growth was almost nil. The basal leaves and the outer half of the stem leaves dried and growth was not resumed in these portions of the plants.

Floral development of buffalo grass in the heavily grazed location preceded that in the moderately grazed area by seven to ten days. The staminate heads were quite abundant in the former area by May 20, but for the most part they were not readily noted until May 28 in the latter location. In general, buffalo grass had completed floral development by July 1. However, during the last part of the months of August and September, vegetative growth was again evident and by September 25 new heads were noted. At this time floral development was not abundant in the heavily grazed location.

Big Bluestem

Big bluestem, a warm season grass, was preceded in initial growth by all other major species (Fig. 19). Growth of this species was first noted in the heavily grazed location April 15. Development in the moderately and non-grazed locations began shortly thereafter, and by April 28, growth was evident in all areas.

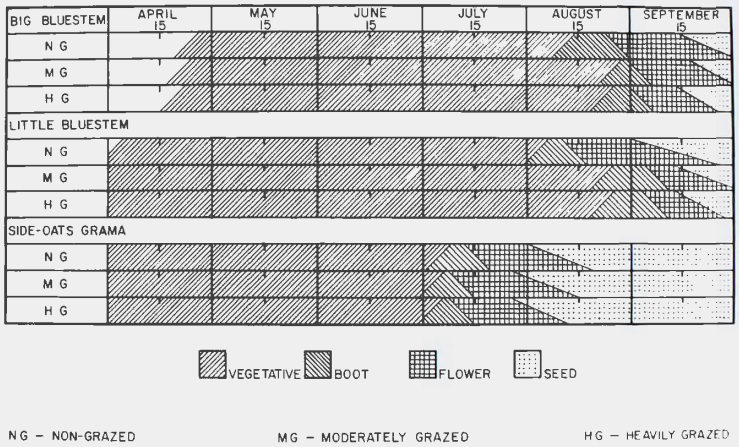

Fig. 19. Seasonal development by dates and growth stages of major grasses on hillside site under different intensities of past utilization.

Average height of big bluestem in the non-grazed location on June 1 was 13.67 inches, or 86.8 per cent of the 15.75 inches total growth for the season. In the moderately grazed pasture slightly over 80 per cent of the total height of 14 inches was produced by June 1, while in the heavily grazed area the height was 4.75 inches, also over 80 per cent of the total increment. Average number of leaves per plant in the non-grazed, moderately grazed, and heavily grazed areas was 8.67, 8.0, and 8.67, respectively.

Floral development was initiated first under non-grazed conditions. In this area some of the big bluestem plants had initiated floral development within the boot as early as August 6. However, most of the heads dried and development in most cases did not extend beyond the boot. The first complete inflorescences were noted August 20; however, very few heads were noted prior to September 1. Flowering of big bluestem continued throughout September. Many of the inflorescences were partially enclosed by the sheath and very few normal heads were developed.

Floral development was nearly the same in the two grazed pastures. Under these conditions inflorescences were not noted until after September 1. The plants in the heavily grazed location were greatly reduced in stature as compared to those in the other two areas (Fig. 20). Total average height of the flower stalks was 16 inches in the heavily grazed location while in the moderately grazed pasture it was 26 inches. These are compared with an average height of 32 inches under non-grazed conditions.

Big bluestem was affected by the drought periods, especially under grazed conditions. In the heavily grazed location many of the basal leaves

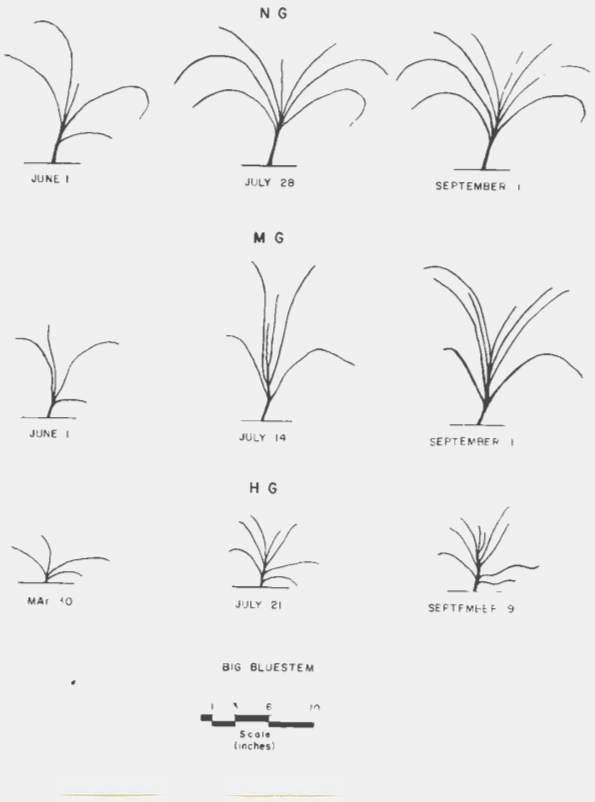

Fig. 20. Sketches represent typical plants of big bluestem at three different times during the growing season.

dried during drought and did not recover. The same was true in the moderately grazed and non-grazed locations but to a lesser extent.

Little Bluestem

In the non-grazed pasture little bluestem produced an average seasonal increment of 13.25 inches, as compared to 9.67 inches for the moderately grazed and 5.2 inches in the area heavily grazed. Growth was initiated at approximately the same time in grazed areas, while in the non-grazed prairie it was slightly later (Fig. 19).

Little bluestem had produced over 80 per cent of the total increment in the non-grazed location by June 1. During June and July, however, growth was slight and very little increase was noted. Floral development had begun by August 1, and the first inflorescences were produced by August 10. At first only scattered heads were noted but during the latter part of the month little bluestem was flowering profusely. Numerous inflorescences remained partially enclosed within the boot and actual floral development was poor.

In the moderately grazed area few heads were produced. Growth here was almost nil during the drought periods. Also, on the heavily grazed area, production ceased during the periods of drought and floral development was extremely poor. Floral development did not begin in the grazed locations until about August 20, and inflorescence development was somewhat retarded. In the heavily grazed location, partial heads were noted September 2; whereas, under moderately grazed conditions, they were not noted until September 5. There were very few heads produced under grazed conditions. A vast difference existed between the stature of the individual plants in the three areas (Fig. 21).

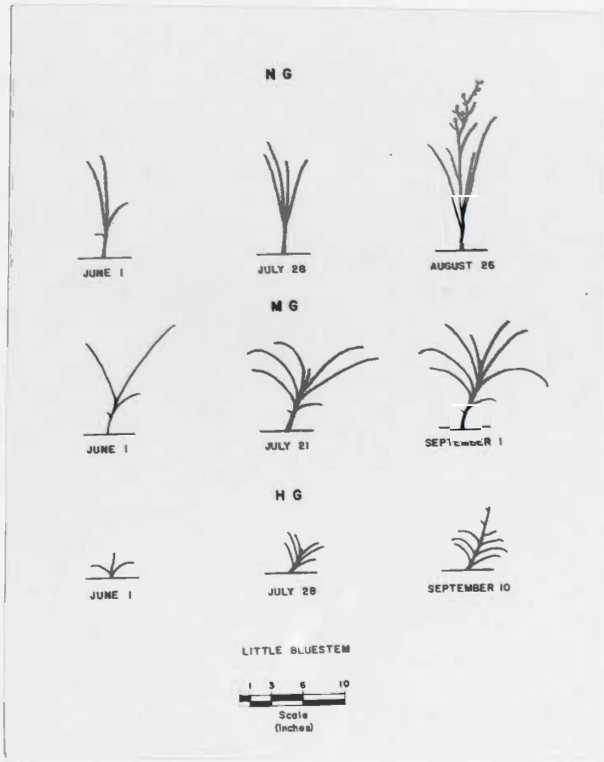

Fig. 21. Little bluestem at different stages of development. Very few inflorescences were produced in the grazed locations.

Side-oats Grama

Side-oats grama was one of the earlier grasses to begin growth. It had produced quite a sizeable amount of forage by April 1 in all three areas (Fig. 19). This species produced an average increment of 12.57 inches by June 1 under non-grazed conditions, which was slightly over 80 per cent of the seasonal increment of 15.75 inches. At this time it had produced an average of four leaves per plant which corresponded with the same number produced in the grazed locations. In the moderately grazed grassland, the seasonal increment was 9.92 inches, of which 68 per cent (6.74 inches) had been produced by June 1. The average total number of leaves per plant in this area was 6.62. Under heavily grazed conditions, however, an average of nine leaves per plant was produced and the seasonal increment was only 5.8 inches. On June 1, the increment was 3.67 inches, only 63.3 per cent of the total increment. The plants in the heavily grazed area were greatly reduced in stature (Fig. 22).

Floral development of side-oats grama began at about the same time under all three conditions of past utilization. At the time of seed production, culms were tallest in the moderately grazed location (Fig. 23). By July 1, inflorescence development within the boot had begun in all three areas. Flower stalks and inflorescences were evident first in the heavily grazed location. The June drought obviously affected the development of side-oats grama. In all areas the earlier inflorescences produced were the smallest and had a relatively reduced number of spikelets. During August many of the plants dried before all of the spikelets emerged beyond the boot.

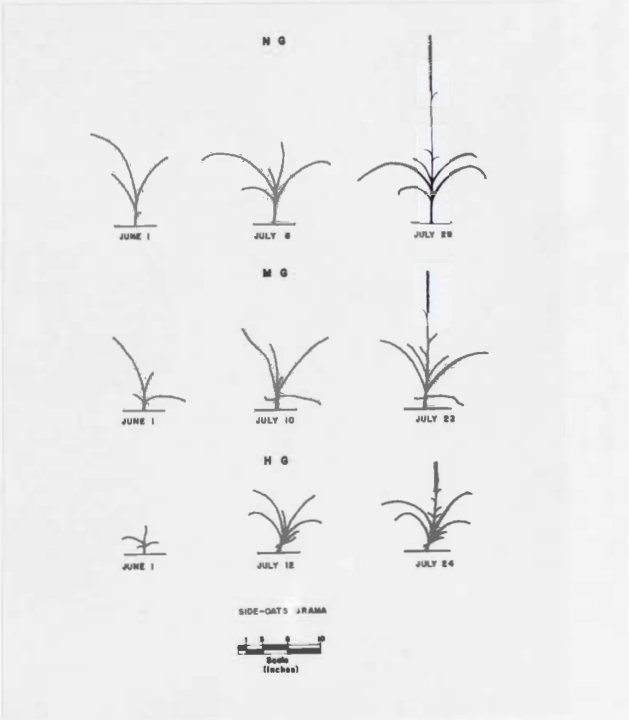

Fig. 22. Sketches of individual side-oats grama plants at three different periods of development.

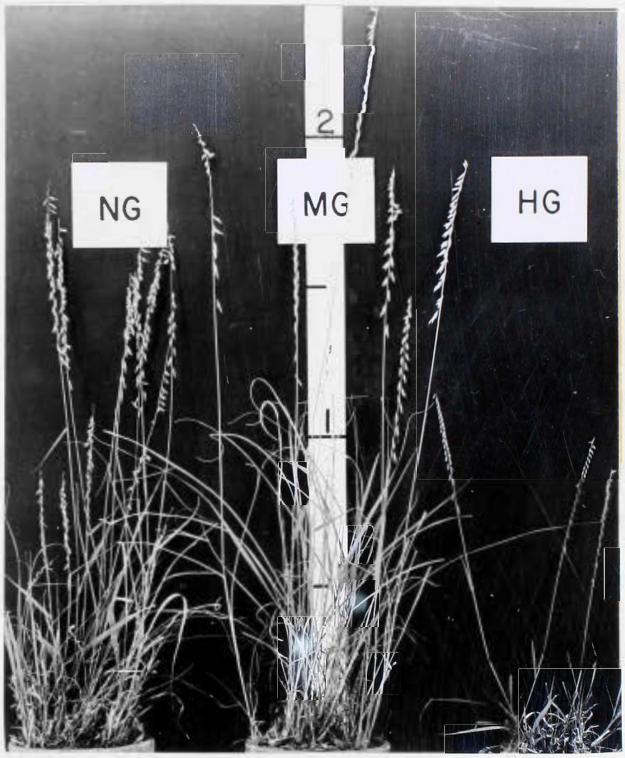

Fig. 23. Side-oats grama showing differences in growth form under the various degrees of past utilization. Scale is in feet.

Caryopsis production in side-oats grama was near completion August 15. By this time many of the earlier heads had matured and some of the seed had shattered.

Fall growth was evident during the last two weeks of September when moisture conditions were favorable. Many new tillers were produced but no new inflorescences were noted.

Seasonal Forage Yields

On the non-grazed upland, total forage yield from all quadrats was 2057.7 pounds per acre (Table IV). Side-oats grama and big bluestem made up 34.12 and 32.67 per cent of the total yield, respectively. Little bluestem averaged only 6.56 per cent of the composition but 16.95 per cent of the yield. Blue grama, which comprised 20.51 per cent of the composition, accounted for only 10.62 per cent of the yield. Western wheatgrass yielded 1.7 per cent of the total forage, while the remaining 3.95 per cent was made up of other grasses such as tall and hairy dropseed.

Blue grama and side-oats grama furnished over 60 per cent of the total 1729.5 pounds per acre forage yield on the moderately grazed upland. Buffalo grass and western wheatgrass contributed 271.5 and 157.6 pounds per acre, respectively. Big bluestem, found sparsely in this area, produced 4.12 per cent of the total yield.

Seasonal forage production on the heavily grazed upland was only 1101.8 pounds per acre. The three main contributors at this location were blue grama, buffalo grass and side-oats grama, composing 54.59, 33.28, and 10.5 per cent of the total yield, respectively. Western wheatgrass was of lesser importance and produced only 1.22 per cent of the total yield. The remainder of yield was comprised of three-awn grasses and sand dropseed.

TABLE IV. Seasonal production and yield of major grass species on upland locations from each degree of past utilization.

	Pounds Per Acre		
SPECIES	Non-Grazed	Mod. Grazed	Heavily Grazed
Little Bluestem	348.8		
Big Bluestem	672.4	71.2	
Side-oats Grama	702.2	555.4	115.7
Blue Grama	218.6	631.9	601.5
Buffalo Grass		271.5	366.7
Western Wheatgrass	35.6	157.6	13.4
Other Grasses	80.1	41.9	4.5
Total Yield	2057.7	1729.5	1101.8

Grass production on the non-grazed hillside averaged 2242 pounds per acre (Table V). Little bluestem, big bluestem and side-oats grama were the main grasses, as they made up 33.98, 28.51, and 26.03 per cent, respectively, of the yield. Blue grama was next in importance and composed 8.5 per cent of total forage production. The remaining 2.98 per cent included switch grass (Panicum virgatum) and hairy dropseed.

Total forage production on the moderately grazed hillside was 1599.6 pounds per acre, which was 38.65 per cent less than that produced under non-grazed conditions. Slightly over 40 per cent of the total yield was made up of side-oats grama. Big and little bluestem composed 28.04 and 17.3 per cent of the yield, respectively. Blue grama, which was present in half of the quadrats, contributed 3.73 per cent of the seasonal yield. Other grasses such as hairy dropseed and indian grass (Sorghastrum nutans) furnished the remaining 10.91 per cent.

On the heavily grazed hillside, an average of 1208.9 pounds per acre of forage was produced. This was only 53.92 per cent as much as was produced on the non-grazed hillside. Big bluestem accounted for 424.6 pounds per acre or 35.12 per cent of the total yield. Side-oats grama was of nearly equal importance and contributed 31.07 per cent of the total. The reduction of little bluestem was evident in this area as it yielded only 32.1 pounds per acre. Of the total yield, 143.4 pounds per acre was made up of other grasses including hairy grama, three-awn grasses, tumble grass, and sand dropseed.

TABLE V. Seasonal production and yield of major grass species on hillside sites from each degree of past utilization.

	Pounds Per Acre		
SPECIES	Non-Grazed	Mod. Grazed	Heavily Grazed
Little Bluestem	761.9	276.8	32.1
Big Bluestem	639.1	448.6	424.6
Side-oats Grama	583.7	640.0	375.6
Blue Grama	190.5	59.7	
Buffalo Grass			232.2
Other Grasses	66.8	174.5	143.4
Total Yield	2242.0	1599.6	1208.9

Number of Tillers Producing Inflorescences

Quite a vast difference was found in the number of tillers that produced flower stalks under the different intensities of previous utilization. Little bluestem, which was found primarily on the hillside sites, produced over four times as many flower stalks per 100 tillers in the non-grazed area as it did on the grazed locations (Table VI). The per cent of tillers producing inflorescences was 33, 7, and 8, respectively, for the non-grazed, moderately grazed, and heavily grazed locations.

Inflorescence production of big bluestem was greatest on the heavily grazed hillside where 3.3 per cent of the tillers produced flower stalks. Production was least under moderately grazed conditions where only one per cent of the tillers developed inflorescences. In the non-grazed area only two inflorescences were produced per one hundred tillers.

Side-oats grama was second only to little bluestem in inflorescences produced per 100 tillers. Development was greatest under non-grazed condition where 11 per cent of the tillers developed inflorescences. Four and one-half and 8.5 per cent of the tillers produced flower stalks in the moderately grazed and heavily grazed areas, respectively.

Floral development of blue grama was relatively poor on all three uplands. Under heavily grazed conditions 33 per cent of the tillers developed inflorescences, as compared with 2.0 and 1.0 per cent, respectively, on the non-grazed and moderately grazed uplands.

Western wheatgrass produced very few inflorescences and there was no significant difference between the production on three uplands. The greatest production averaged 1.0 per cent in the grazed areas and the least was .89 per cent in the non-grazed location.

TABLE VI. Per cent of tillers of each species producing inflorescences under each degree of past utilization.

SPECIES	Non-Grazed %	Mod. Grazed %	Heavily Grazed %
Little Bluestem	33.0	7.0	8.0
Big Bluestem	2.0	1.0	3.3
Side-oats Grama	11.0	4.5	8.5
Blue Grama	2.0	1.0	3.3
Western Wheatgrass	.89	1.0	1.0

Yield of Caryopses

Hairy grama yielded a greater percentage of caryopses per one hundred florets than any of the other grasses studied (Table VII). It produced an average of 15.3 caryopses per hundred florets under moderately grazed conditions, 14 caryopses per hundred florets under heavily grazed conditions but only 8.5 where no grazing was permitted.

Caryopsis production of the remainder of the grasses was, in general, poor. Little bluestem yielded only one caryopsis per hundred florets in the non-grazed area and 1.5 in the moderately grazed. No caryopses were produced on the heavily grazed location.

Big bluestem, one of the most important grasses, produced fewer caryopses per hundred florets than any other major grass. Less than one-half of one per cent of the florets from the non-grazed and moderately grazed locations contained caryopses, and none were produced in the heavily grazed area.

Caryopsis yield of side-oats grama was greatest in the heavily grazed area where an average of 4.67 per cent of the florets contained caryopses. In each of the other two areas only one-half of one per cent of the florets contained caryopses.

Blue grama also produced the greatest percentage of caryopses under heavily grazed conditions. In this area, percentage caryopses yield was 3.67 per cent, as compared to 0.4 per cent in the non-grazed and 1.0 per cent in the moderately grazed locations.

Western wheatgrass showed a uniform increase in caryopses production with increase in degree of utilization. In the non-grazed location 1.5

TABLE VII. Average per cent of florets containing caryopses for each species under each degree of past utilization.

SPECIES	Non-Grazed %	Mod. Grazed %	Heavily Grazed %
Little Bluestem	1.0	1.5	0.0
Big Bluestem	0.3	0.3	0.0
Side-oats Grama	0.5	0.5	4.67
Blue Grama	0.4	1.0	3.67
Western Wheatgrass	1.5	2.5	3.6
Hairy Grama	8.5	15.3	14.0

per cent of the florets contained caryopses as compared with 2.5 per cent and 3.6 per cent in the moderately and heavily grazed pastures, respectively.

DISCUSSION

The principal factor affecting growth of vegetation in the mixed prairie is cyclic climatic conditions. Extended periods of drought occur and mid-season droughts are common nearly every year (Weaver and Albertson, 1956). During the growing season of 1959, when this study was conducted, two definite drought periods occurred, both greatly affecting vegetative growth. In each case, the heavily grazed pasture was first to exhibit the detrimental effects of drought, followed by the non-grazed and then the moderately grazed locations (Tomanek, 1948).

The cover of perennial grasses was greatest on the heavily grazed locations. However, a greater abundance of less desirable grasses was found here and the vigor of the plants had been greatly reduced. Big bluestem and side-oats grama, found abundantly on the non-grazed upland, were greatly reduced under grazed conditions and the former was absent from the area heavily grazed. Buffalo grass showed a definite increase in abundance with increase in intensity of past utilization.

Little bluestem was greatly reduced on the grazed hillsides. Blue grama, which occurs in limited amounts on the properly stocked hillsides, was not found on the heavily grazed area. However, buffalo grass more than replaced it, and was the most abundant species here.

All grasses, with exception of big bluestem, had started growth by April 1. Western wheatgrass, a cool season perennial, was the first major grass to initiate growth. A large percentage of the seasonal incre-

ment of the major grasses had been produced by June 1. The cause of this was attributed to the fact that during May, rainfall was above average, whereas a drought occurred in June and greatly retarded further vegetative growth.

The earlier floral development of blue grama under heavily grazed conditions was assumed to be due to the lack of mulch and lack of competition with the taller grasses. In the non-grazed prairie blue grama occurred between clumps of the taller grasses and could not readily compete with them.

Of the grasses investigated, big and little bluestem appeared to be affected most by grazing. Floral development of both species began in the non-grazed prairie about two weeks prior to that in the grazed areas. The vigor of these grasses had been reduced by grazing and as a result the plants were greatly reduced in stature.

Side-oats grama showed little difference in periods of development under the three intensities of grazing.

Moisture seemed to be the most important limiting factor affecting floral development. The most active periods of anthesis usually occurred within a week following the periods of rainfall. If rainfall did not occur, the plants assumed a semi-dormant condition. However, with the advent of favorable moisture conditions, inflorescence development was initiated and in most cases flower stalks were formed rapidly.

The non-grazed location produced the greatest seasonal yields, as forage production decreased in areas of grazing. Although the yield was much reduced in the moderately grazed pasture it was greater than that produced in the heavily grazed location. Seemingly, the pastures with a denser cover of vegetation produced less forage than that of the lesser cover

in the non-grazed prairie. This was attributed primarily to the decrease in abundance and stature of the taller grasses and the increase of short grasses in grazed locations.

An analysis of inflorescence production showed quite a considerable variance under the three degrees of past utilization. One-third of the tillers of little bluestem produced inflorescences in the non-grazed location. Under grazed conditions the plants did not respond as well to the rainfall following drought and inflorescence development was greatly retarded.

Big bluestem produced very few inflorescences; however, the greatest number produced was in the area heavily grazed. Floral development did not begin as soon here and was therefore affected less by the August drought. Blue grama showed a similar response as the greatest number of flower stalks were produced in the two areas of grazing extremes. Presumably, in the moderately grazed area blue grama competes very well with other grasses and is the major dominant. In this location a rather large amount of forage is produced and only small amounts of seed develop. In the other areas, grazing pressure and competition are somewhat extreme. Thus, greater stress is placed on reproduction than on forage production. This hypothesis is further supported by the fact that blue grama yielded the greatest percentage of caryopses per 100 florets in the heavily grazed location, and the greatest percentage of the forage yield in the moderately grazed prairie.

Side-oats grama produced the greatest percentage of inflorescences in the non-grazed area, but the highest number of caryopses per 100 florets was produced in the heavily grazed area. Extremely few caryopses were found in the moderately and non-grazed locations. Western wheatgrass was

greatly affected by the June drought and floral development of this species was very poor.

Hairy grama was commonly found on the rims of hillsides. It was the earliest grass to produce inflorescences and was the only species to complete floral development, seemingly unaffected by the August drought. As a result, hairy grama yielded a greater percentage of caryopses per 100 florets than did any other major species.

SUMMARY

Three pastures were selected for study with reference to their past history of grazing, and were classified as non-grazed, moderately grazed and heavily grazed. Exact study locations were then established on upland and hillside sites of each pasture. The primary objectives of this study were to determine the seasonal development and seed production of buffalo grass (Buchloe dactyloides), blue grama (Bouteloua gracilis), side-oats grama (B. curtipendula), western wheatgrass (Agropyron smithii), big bluestem (Andropogon gerardi), and little bluestem (A. scoparius) in locations subjected to three different intensities of grazing during past years. To accomplish this, a detailed study of the differences between the three pastures was made along the following lines: (1) basal cover and composition; (2) seasonal development of the grasses; (3) forage yields; (4) inflorescence production; and (5) yield of caryopses.

Climatic conditions during the period of study were cyclic, and in general, unfavorable for plant growth. Two mid-season drought periods occurred and temperatures ranged above normal during their occurrence. However, seasonal precipitation was above normal and temperatures as an average were lower than normal.

Average basal cover of the non-grazed, moderately grazed and heavily grazed upland locations was 36.27, 41.30, and 55.31 per cent, respectively. Side-oats grama, big bluestem and blue grama were the major dominants in the non-grazed area. In the grazed locations the short grasses, blue grama and buffalo grass, were of greater abundance and the taller grasses were greatly decreased.

Average basal cover on the hillside site of the non-grazed prairie was 28.48 per cent, while on the moderately grazed and heavily grazed areas it was 32.39 and 42.87 per cent, respectively. Big bluestem and side-oats grama were two of the major dominants on the hillsides. Little bluestem and blue grama, both found on the non-grazed area, were greatly reduced under grazing and buffalo grass was a major contributor on the heavily grazed site.

With exception of big bluestem, growth of all major grasses investigated was initiated by April 1. Western wheatgrass was the first to show signs of growth and by June 1 flower stalks were being formed. However, no inflorescences were produced until June 7. The drought during June greatly retarded floral development of western wheatgrass and very few heads were produced.

Blue grama produced slightly over 80 per cent of its seasonal increment during the first half of the growing season. During drought periods the tips of many of the leaves dried to a brownish color and many of the basal leaves dried and fell off. In the heavily grazed location the most active period of anthesis was from August 18 to September 1. Development followed much the same course in the other areas but was four to eight days later. The stature of the plants varied greatly in the areas of different

grazing intensities and under conditions of heavy grazing the plants were greatly reduced.

Specific measurements were not conducted on buffalo grass, but general observations were presented. This species, found primarily on the grazed areas, had started growth by April 1. Inflorescences had been produced in the heavily grazed area by May 2; however, none were noted in the area moderately grazed until May 28. By July 1 floral development had reached completion and little growth was noted from this time until after the early fall rains.

Of the major grasses, big bluestem was the latest to initiate growth. Development of this species began in all three areas within a week, being noted first in the heavily grazed and last in the non-grazed locations. A large portion of the seasonal increment was produced by June 1. Floral development within the boot was first noted August 6 in the non-grazed prairie. Development in the grazed locations did not begin until August 22. However, the major portion of inflorescence exsertion occurred during September in all three areas.

Floral development of little bluestem was first obvious in the non-grazed location August 1. Development followed in the grazed location by August 20, but in general the most active period of anthesis occurred during mid-September.

Very little difference was noted in the development of side-oats grama under the various intensities of grazing. Growth had started by April 1 in all areas and floral development was initiated soon after July 1. Flowering was at a maximum during late July, and the first seed was set by August 1.

Seasonal forage yields varied considerably with the intensity of grazing. The non-grazed location consistently out yielded the grazed areas and produced nearly twice as much as did the heavily grazed location. The moderately grazed pasture produced somewhat less than did the non-grazed, but considerably more than the heavily grazed.

The percentage of tillers producing inflorescences varied somewhat with degree of grazing. Little bluestem produced over four times as many inflorescences per 100 tillers in the non-grazed prairie as it did in the grazed locations. Big bluestem, blue grama and western wheatgrass produced very few flower stalks and did not show any great variation under the different grazing intensities. Side-oats grama also produced the largest percentage of flower stalks under non-grazed conditions.

Caryopses production was poor for all species except hairy grama, which produced 8.5, 15.3, and 14 caryopses per 100 florets in the non-grazed, moderately grazed, and heavily grazed locations, respectively. Big and little bluestem produced no caryopses on the heavily grazed location and only very few in the other areas. Side-oats grama, blue grama and western wheatgrass produced the greatest percentage of caryopses in the heavily grazed location and the least number in the non-grazed prairie.

The results obtained from this investigation do not warrant the formulation of any definite conclusions. Due to great variation in seasonal climatic conditions, it is presumed that plant development varies somewhat from year to year. A continuation of this investigation over a period of years should be of value in explaining and confirming the observed results of the present study.

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